

IN-SITU XRF AND GAMMA RAY SPECTROMETER FOR MARS SAMPLE RETURN MISSION; Lo I Yin and Jacob I. Trombka, NASA Goddard Space Flight Center, Laboratory for Astronomy and Solar Physics, Code 682, Greenbelt, MD 20771, Larry G. Evans, Astronomy Programs, Computer Sciences Corporation, Beltsville, MD, and Steven W. Squyres, Center for Radiophysics and Space Research, Cornell University, Ithaca, NY

We propose a combined in-situ x-ray fluorescence (XRF) and passive gamma-ray spectrometer instrument for the chemical elemental analysis of various Martian surfaces and samples. The combined instrument can be carried on board a rover. The passive γ -ray or the neutron-excited γ -ray system would be used to determine the elemental composition of the Martian surface while the rover is in motion. The XRF system would be used to perform analysis either on the Martian surface or on collected samples when the rover is stationary. This latter function is important both in cataloguing the collected samples and in the selection of samples to be returned to earth. For both systems, data accumulation time would be on the order of 30 minutes. No sample preparation would be necessary.

XRF is a well-established and successful technique in performing in-situ chemical analysis of planetary surface samples. In previous planetary missions such as Viking and Venera, XRF measurements were made using radioisotopes as excitation sources and proportional counters as energy-dispersive detectors. Although our instrument does not preclude the use of radioisotopes we emphasize here the use of a miniature x-ray generator as the excitation source and mercuric iodide as the energy-dispersive detector.

A low-power (10 W) battery-operated x-ray generator was developed at Goddard Space Flight Center several years ago. The x-ray generator weighs 6 kg, is capable of supplying 68 kV and 100 microamps of anode current, and is powered by a 18-V battery. It has a grounded anode with no high-voltage cables. Such an x-ray generator with variable spectral distribution can provide far higher x-ray fluxes than radioactive sources. Recently, similar battery-operated x-ray generators have also become commercially available.

The energy resolution of room-temperature mercuric iodide detectors has been improving steadily in recent years. Under laboratory conditions it is now gradually approaching the resolution of cooled Si(Li) detectors. However, presently available mercuric iodide detectors with good stability and acceptable energy resolution for the Mars sample return mission have sensitive areas of only a few mm². Such small detection areas need not be a problem with the proposed XRF instrument because of the high x-ray flux available from the x-ray generator. Therefore the combination of a miniature x-ray generator with a mercuric iodide detector should provide an in-situ XRF instrument with energy resolution and detection

efficiency not achievable by previous planetary instruments.

Table I lists some of the elements which can be detected by a passive γ -ray spectrometer using a 7.5x7.5 cm NaI(Tl) crystal. The expected integration time for each element to reach 10% uncertainty is calculated using methods similar to those in Evans and Squyres¹. The neutron spatial and energy distribution, and consequently the γ -ray flux, is highly sensitive to the H content. Therefore calculations were carried out for different cases of soil and H₂O: with 1% H₂O, with 25% H₂O, and with a "dry" layer of soil with 1% H₂O covering soil with 25% H₂O for three different thicknesses of the top layer. Table I shows that while the rover is in motion integration time on the order of 30 minutes could provide sufficient information concerning H, K, and Fe. When the rover is stationary, most of the elements in Table I could be analyzed in a few hours. Of course, if weight and power constraints permit the use of a neutron generator, the integration times in Table I could be reduced substantially, and additional elements could be detected.

Table I. Integration time (hours) to measure an element to 10% uncertainty by the passive γ -ray spectrometer

Element	Mode*	Homogeneous soil + H ₂ O		Layer soil with 1%H ₂ O over soil+25%H ₂ O		
				Thickness of upper layer		
		soil+ 1%H ₂ O	soil+ 25%H ₂ O	20g/cm ²	50g/cm ²	100g/cm ²
Fe	C	0.7	0.3	0.5	1.1	1.1
Si	C	4.0	1.6	2.8	7.6	7.8
Cl	C	3.5	1.4	2.3	5.8	5.9
H	C	68.0	0.03	0.3	5.7	74.0
Si	I	0.1	0.5	0.2	0.1	0.1
Mg	I	2.1	11.0	3.7	2.5	2.1
Fe	I	0.2	1.0	0.3	0.2	0.2
K	R	0.3	0.5	0.4	0.3	0.3
Th	R	6.0	9.4	7.0	6.0	6.0

*Mode: C - γ rays produced by neutron capture

I - γ rays produced by neutron inelastic scattering

R - γ rays produced by natural radioactivity

It should be noted that both the XRF and the γ -ray spectrometer will share much of the analyzing electronics beyond their respective amplifier stage. Because of the relatively coarse resolution of the NaI(Tl) spectrometer, a single analog-to-digital converter will be sufficient to accommodate both XRF and γ -ray spectra. Thus economy in both weight and cost can be realized in such a combined XRF and γ -ray instrument.

1. Evans, L.G. and Squyres, S.W. (1987) J. Geophys. Res., 92, 9153-9167.